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EXAMINER	
COOLEY, CHARLES E	
ART UNIT	**PAPER NUMBER**
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Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	Application No.	Applicant(s)
	10/621,379	FLOHR ET AL.
	Examiner	Art Unit
	Charles E. Cooley	1723

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *12 October 2005*.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-17* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-17* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☒ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *12 October 2005* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☒ All b)☐ Some * c)☐ None of:

1.☒ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

FINAL OFFICE ACTION

Priority

1. Receipt is acknowledged of papers submitted under 35 U.S.C. § 119, which papers have been placed of record in the file.

Information Disclosure Statement

2. Regarding Applicant's remarks on the stricken through EP 623786 A1 document, note this document also appears (and is initialed) on the IDS filed 17 JUN 2004. It was thus stricken through as being a duplicate citation.

Specification

3. The disclosure is objected to because of the following informalities:

a. Pages 7-8 refer to Figures 4 and 5 which do not exist. A descrptipn of each of Figures 4a, 4b, 5a, and 5b is required.

Appropriate correction is required. Applicant's remarks on this objection are not persuasive. The MPEP citation referred to involves the Brief Description of Drawings section of the specification, not the detailed description section which is the section objected to (appearing on pages 7-8).

4. The abstract is acceptable.

5. The title is acceptable.

Claim Rejections - 35 USC § 102

6. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

7. Claims 1-17 are rejected under 35 U.S.C. 102(b) as being clearly anticipated by Schulte-Werning (US 5,735,126).

The patent to Schulte-Werning '126 clearly discloses the recited vortex generator and method as seen in Figs. 2-15 and as noted below (emphasis added). A walled flow duct 6 for a main flow 4 is provided. Figs. 14-15 show side surfaces of the vortex generators including a plurality of outlet openings 227 of different geometrical configuration, namely the openings are at different special orientations with respect to the respective side surface of the vortex generator. Fig. 9 teaches that the openings for the fluid injection can be formed as a slit 222. The openings introduce a targeted secondary flow or axial impulse of fluid (see the flow arrows in Figs. 12-15) in the direction of the main flow 4 into the vortex or vortices generated by the vortex generator (see Figs. 1 and 12-15). Countercurrent vortices located in the axis of the main flow 4 are shown in Figs. 4 and 6.

More particularly, the patent to Schulte-Werning '126 teaches a vortex generator and method, namely that in combustion chambers of gas turbines, the hot-gas flow flowing via the corresponding burners and prepared in the mixing zone before the turbine by admixing the mass flow not flowing via the burners must as a rule be set to

the temperature profile adequate for the turbine. The quality resulting from this admixing is normally controlled via the dimensioning of the cross-section and the number of air-inlet openings. These air-inlet openings, which at the same time act as mixing-air nozzles, not only provide for the requisite penetration depth of the colder air, flowing through there, into the hot-gas flow and thus produce the macroscopic turbulence necessary for rapid mixing but also simultaneously provide for an adequate uniform distribution of the colder air feed via the combustion-chamber wall. Since these two effects are actually contrary effects, for larger nozzles lead to greater penetration depth and poorer equipartition and thus to hot or cold streaks in the hot-gas flow, there are limits to the mixing uniformity achievable, which limits are reflected in an increase in the pollutant emissions and a reduction in efficiency.

Accordingly, in the case of a combustion chamber and a method of the type mentioned at the beginning, one object of the invention, as defined in the claims, is to improve the admixing quality and reduce the thermal loading of the combustion chamber; at the same time it is an object of the invention to ensure that the pollutant emissions are minimized and the efficiency is maximized.

The improvement in this admixing quality, which achieves the other objectives, is achieved by the two abovementioned effects being separated from one another in such a way that they are each optimized when considered by themselves.

The macroscopic vortex motions in the hot-gas flow are produced by vortex-producing elements, simply called vortex generators below, which are preferably fixed to the combustion-chamber wall or combustion-chamber walls in the mixing section,

downstream of the primary zone. These vortex generators serve to produce the requisite, intensive, large-scale mixing motion between hot gases and the mixing air, to be intermixed, in the form of a secondary flow, which behaves independently relative to the mixing-air stream, in contrast to the conventional procedure.

The mixing air is now fed uniformly to the hot gas via a number of small bores in the combustion-chamber wall in such a way as to aim for a supercritical blow-out rate which at the same time ensures effusion cooling. On account of the supercritical blow-out rate aimed at, the mixing air penetrates the marginal zones of the vortices induced by the vortex generators, is carried away from the wall by these vortices and accordingly rapidly mixes with the hot gases. Since the vortex generators are directly exposed to the hot gases, the adequate cooling thus achievable is an indispensable prerequisite for such a mixing section.

The effusion cooling effect is based mainly on the inner convective cooling when the mixing air passes through the passage openings and on the possible formation of a cooling-air film on the hot-gas side. If the ratio between the impulse of the mixing-air stream and that of the hot-gas flow is small enough, the flow boundary layer is not pierced on the hot-gas side by the mixing air and a cooling-air film can form in an optimum manner. If this blow-out rate exceeds a critical value, the mixing-air stream penetrates the hot-gas flow without forming a cooling-air film. In a suitable design, however, the internal wall cooling effect increases simultaneously with increasing blow-out rate in such a way that the overall cooling effect can be kept approximately constant.

In the supercritical range, the penetration depth of the mixing-air stream into the hot-gas flow near the vortex generators can be kept small, at least one order of magnitude smaller than in the case of the conventional air-inlet openings, since it merely has to be large enough that, although the mixing air penetrates the vortices, the mixing-air stream itself does not have to provide for the requisite large-scale turbulence. Therefore no large diameters are necessary and the mixing air may be fed over a large area.

The proposed mixing section can also be adapted to various load states of the gas turbine. If the pressure gradient available for the intermixing is designed to be variable, for example via an adjustable supply restrictor, the mixing-air flow to be intermixed can also be controlled. If the blow-out rate changes in the process from the supercritical to the subcritical range, the effusion cooling effect remains the same over a large load range despite a large variation in the mixing-air flow. In this way, not only is the air to be intermixed fed to the mixing process over a large area and thus the mixing quality overall increased, but the wall of the mixing section is also protected from excessive temperatures irrespective of the mixing output.

The direction of flow of the media is indicated by arrows, FIG. 1, as apparent from the shaft axis 15 shown in the drawing, shows that the combustion chamber here is an annular combustion cheer 100 which essentially has the form of a continuous annular or quasi-annular cylinder. In addition, such a combustion chamber may also consist of a number of axially, quasi-axially or helically arranged and individually self-contained combustion spaces. The combustion chamber per se may also consist of a

single tube. Furthermore, this combustion chamber may be the single combustion stage of a gas turbine or a combustion stage of a sequentially fired gas turbine. In the direction of the oncoming flow, the annular combustion chamber 100 according to FIG. 1 consists of a primary combustion zone 1, which is then followed by a mixing section 2, downstream of which acts a secondary combustion stage 3, which is preferably designed as inflow to a turbine. The burner as well as the fuel feed and the primary-air feed are essentially placed at the start of the primary combustion zone 1 and are symbolized, by arrow 13 in the present FIG. 1. The primary combustion zone 1 is encased by a concentric tube 11 at a distance apart; flowing in between in the counterflow direction is a quantity of cooling air 12 which ensures convective cooling of the primary combustion zone 1. After it has passed through, this air may then go for example through the burners. The hot gases 4 from the primary combustion zone 1 flow into the mixing section 2; the inner wall 6 and the outer wall 5 of this mixing section 2 are fitted with a row of vortex generators 200 which may be arranged in different ways in the peripheral direction of the said walls. The different shapes, modes of operation and arrangements of the vortex generators 200 will be dealt with in more detail further below. In the region of the vortex generators 200, the mixing section 2 is encased by a chamber 10 into which mixing air 8 flows via control members 9 and is then distributed there via the various openings in the inner wall 6 and outer wall 5 as well as by the vortex generators 200 in order subsequently to flow into the mixing section 2. The openings referred to are apparent, for example, in FIGS. 8, 10, 12, 14 and 15; these figures will be explained in more detail further below. <u>The mixing air 8 is actually of</u>

considerable quantity, for example **up to 50%** and more of the total mass flow. In the case of such a quantity of mixing air, the blow-out rate into the mixing section 2 is supercritical, for which reason a cooling film cannot actually form along the walls 5, 6. It is of course the case that the air 8 possibly intermixed decreases significantly during pronounced throttling of the mixing air 8 via the control members 9, for which reason the quantity of the hot-gas flow 4 then increases. Once this mixing-air quantity 8 reaches the subcritical blow-out rate, a cooling film then always forms along the walls 5, 6, as a result of which sufficient wall cooling is still guaranteed. The aim, however, is actually to achieve a supercritical blow-out rate in accordance with the intended use, since the mixing air 8 then penetrates the marginal zones of the vortices initiated by the vortex generators 200 arranged there. The inflowing mixing air 8 is carried away from the walls 5, 6 by these vortices, whereby it rapidly mixes with the hot gases 4 flowing through the combustion chamber 100. In addition, openings all around the vortex generators 200 (cf. FIG. 15 below) adequately cool the vortex generators 200 in the face of the hot gases 4. The supercritical blow-out rate also ensures that the penetration depth of the mixing air 8 into the hot gases 4 in the region of the vortex generators 200 can be kept small. It need only be so large that, although the mixing air 8 penetrates the vortices initiated by the vortex generators 200, the inflowing mixing air 8 does not have to provide for large-scale turbulence. For this reason, the openings also do not have a large cross-section or diameter, in which case the mixing air 8 can be introduced over a large area inside the mixing section 2. The introduction of the mixing air 8 into the mixing section 2 may of course be controlled as a function of the load of the plant. The

perpendicular connecting edge (cf. 4-7, item 216) of the vortex generators 200 at the same time forms the transition from the mixing section 2 to the secondary stage 3, in which case a constriction of the mixing zone 2 results here, which then leads to a direct jump 14 in cross-section at the start of the secondary stage 3. Depending on the load state of the plant, the variable distribution of the mass flows 4, 8 causes the cooling effect of the mixing air 8 when passing through the walls to be achieved either by the heat transfer in the interior of the openings alone or in combination with the cooling film. The first case is a supercritical case having high mass flow and high supply pressure, and the second case is a subcritical case having low mass flow and low supply pressure. Accordingly, the mixing configuration thus formed is variable in the sense that the mixing-air flow 8 may be greatly dependent upon load without overheating of the material, in particular of the vortex generators 200 and the walls 5, 6, occurring. The design criterion regarding injection geometry is therefore cooling effectiveness depending only slightly on the mixing-air flow 8 over a larger range. A mixing section 2 conceived in such a way is used both in the case of graduated combustion and in burners where it is a matter of being able to operate with a constant fuel/air ratio despite a variable load.

As illustrated schematically in FIG. 1, the combustion chamber according to the invention may be arranged between two fluid-flow machines, for example, a compressor feeding compressed air to the combustion chamber and a turbine connected to receive the working gas produced. Alternatively, the combustion chamber may be placed between a low pressure turbine and a high pressure turbine.

FIG. 1a illustrates an alternative embodiment of an outlet 16 of the third combustion stage 3, which is shaped as a venturi and includes means 17 for injecting fuel at the narrowest constriction of the outlet.

FIG. 2 is a detail from the section plane II--II in FIG. 1 and shows a configuration of vortex generators 200 which are fixed to both the outer wall 5 and the inner wall 6. They are adjacent to one another in the peripheral direction, the flow of the hot gases 4 through the clearance space being afforded by the radial spacing between the opposite points of the vortex generators 200 as well as by the intermediate spaces of the surfaces around which flow occurs freely. The curved lines apparent in this figure are intended to represent the vortices initiated by the vortex generators 200.

FIG. 3 largely corresponds to FIG. 2, the vortex generators 200 here being fixed only to the inner wall 6.

The actual mixing section 2 is not shown in FIGS. 4, 5 and 6. However, the flow of the hot gases 4 is shown by an arrow, whereby the direction of flow is also predetermined. According to these figures, a vortex generator 200, 201, 202 essentially comprises three triangular surfaces around which flow occurs freely. These are a top surface 210 and two side surfaces 211 and 213. In their longitudinal extent, these surfaces run at certain angles in the direction of flow. The side walls of the vortex generators 200, 201, 202, which preferably consist of right-angled triangles, are fixed, preferably gastight, with their longitudinal sides at least to the duct wall 6 already discussed. They are orientated in such a way that they form a face at their narrow sides while enclosing a sweepback angle .alpha.. The face is designed as a sharp connecting

edge 216 and is perpendicular to each duct wall 5, 6, with which the side surfaces are flush. The two side surfaces 211, 213 enclosing the sweepback angle .alpha. are symmetrical in form, size and orientation in FIG. 4 and they are arranged on both sides of a symmetry axis 217 which is equidirectional to the duct axis.

With a very narrow edge 215 running transversely to the duct through which flow occurs, the top surface 210 bears against the same duct wall 6 as the side surfaces 211, 213. Its longitudinally directed edges 212, 214 are flush with the longitudinally directed edges of the side surfaces 211, 213 projecting into the flow duct. The top surface 210 runs at a setting angle .theta. to the duct wall 6, the longitudinal edges 212, 214 of which form a point 218 together with the connecting edge 316. The vortex generator 200, 201, 202 may of course also be provided with a base surface with which it is fastened to the duct wall 6 in a suitable manner. However, such a base surface is in no way connected with the mode of operation of the element.

The mode of operation of the vortex generator 200, 201, 202 is as follows: when flow occurs around the edges 212 and 214, the main flow is converted into a pair of oppositely directed vortices, as shown schematically in the figures. The vortex axes lie in the axis of the main flow. The swirl number and the location of the vortex breakdown, provided the latter is intended, are determined by corresponding selection of the setting angle .theta. and the sweepback angle .alpha.. The vortex intensity or the swirl number is increased as the angles increase, and the location of the vortex breakdown is displaced upstream right into the region of the vortex generator 200, 201, 202 itself. Depending on the use, these two angles .alpha. and .theta. are predetermined by

design considerations and by the process itself. These vortex generators need only be adapted in respect of length and height, as will be dealt with in detail further below with reference to FIG. 7.

In FIG. 4, the connecting edge 216 of the two side surfaces 211, 213 forms the downstream edge of the vortex generator 200. The edge 215 of the top surface 210 running transversely to the duct through which flow occurs is therefore the edge acted upon first by the duct flow.

FIG. 5 shows a so-called "half" vortex generator on the basis of a vortex generator according to FIG. 4. In the vortex generator 201 shown here, only one of the two side surfaces is provided with the sweepback angle .alpha./2. The other side surface is straight and is orientated in the direction of flow. In contrast to the symmetrical vortex generator, only one vortex is produced here on the sweptback side, as symbolized in the figure. Accordingly, there is no vortex-neutral field downstream of this vortex generator; on the contrary, a complete swirl is imposed on the flow.

FIG. 6 differs from FIG. 4 inasmuch as the sharp connecting edge 216 of the vortex generator 202 here that point which is acted upon first by the duct flow. The element is accordingly turned through 180 degrees. As apparent from the representation, the two oppositely directed vortices have changed their direction of rotation.

FIG. 7 shows the basic geometry of a vortex generator 200 installed in the mixing section 2. As a rule, the height h of the connecting edge 216 will be coordinated with the duct height H or the height of the duct part which is allocated to the vortex generator in

such a way that the vortex produced already achieves such a size directly downstream of the vortex generator 200 that the full duct height H is filled by it. This leads to a uniform velocity distribution in the cross-section acted upon. A further criterion which may bring an influence to bear on the ratio of the two heights h/H to be selected is the pressure drop which occurs when the flow passes around the vortex generator 200. It will be understood that the pressure-loss factor also increases at a greater ratio of h/H.

The vortex generators 200, 201, 202 are mainly and preferably used where it is a matter of mixing two flows with one another. The main flow 4 attacks as hot gases the transversely directed edge 215 or the connecting edge 216 in the arrow direction. The mixing air 8 (cf. FIG. 1) is of a quantity which is up to 50% and more of the main flow 4. In the present case, this mixing-air flow 8 is directed upstream and downstream of the vortex generators as well as through the vortex generators themselves into the main flow 4, as is particularly apparent from FIG. 1.

In the examples shown according to FIGS. 2 and 3, the vortex generators are placed flush with one another; these vortex generators may of course be distributed at a distance from one another over the periphery of the mixing section 2. The vortex to be produced is ultimately decisive for the selection of the geometry, number and arrangement of the vortex generators.

FIGS. 8-15 show further vortex generators having various configurations with regard to the passage openings or bores for the inflow of the mixing air into the main flow. These passages may alternatively also be used for introducing a further medium or another medium, for example a fuel, into the mixing section.

FIG. 8 shows duct wall bores 220 which are located downstream of the vortex generators as well as further wall bores 221 which are located directly next to the side surfaces 211, 213 and in their longitudinal extent in the same duct wall 6 to which the vortex generators are fixed. The introduction of the mixing-air flow through the wall bores 221 gives the vortices produced an additional impulse and a cooling effect, which prolongs the life of the vortex generator.

In FIGS. 9 and 10, the mixing-air flow is injected via a slot 222 or via wall bores 223, both arrangements being made directly in front of the edge 215 of the top surface 210 running transversely to the duct through which flow occurs, and in their longitudinal extent in the same duct wall 6 on which the vortex generators are arranged. The geometry of the wall bores 223 or of the slot 222 is selected in such a way that the mixing air, if need be another medium, is fed at a certain injection angle into the main flow 4 and, as a protective film, largely screens the subsequently placed vortex generator from the hot main flow 4 by flowing around the vortex generator.

In the examples described below, the mixing-air flow, as apparent from FIG. 1, is directed into the hollow interior of the vortex generators. The mixing mechanics aimed at relative to the main flow 4 as well as the cooling means for the vortex generators themselves, which is of the utmost importance, are thus provided without having to provide further measures.

The mixing-air flow may of course also be introduced with the aid of a combination of the means already described (FIGS. 8-10) and with the aid of the further means according to FIGS. 11-15 described below. To preserve a certain clarity, the

through-openings with arrows in the various FIGS. 8-14 are only shown qualitatively, whereby it is easily possible for the relevant surfaces or all the surfaces of the vortex generators to be entirely provided with passage openings at a distance from one another, as apparent from FIG. 15.

In FIG. 11, the mixing-air flow is injected via bores 224 which occupy the top surface 210, the inflow of the mixing-air flow taking place transversely to the duct through which flow occurs or to the edge 215. The cooling of the vortex generator is effected here externally to a greater extent than internally. The issuing mixing-air flow, when flowing around the top surface 210, develops at subcritical blow-out rate a protective layer screening the top surface 210 from the hot main flow 4; otherwise, at supercritical blow-out rate, the mixing action develops as described with reference to FIG. 1.

In FIG. 12, the mixing-air flow is injected via bores 225 which are arranged in an echelon inside the top surface 210 at least along the symmetry line 217. With this variant, the duct walls 6 are protected especially effectively from the hot main flow 4, since the mixing-air flow is introduced first of all at the outer periphery of the vortices.

In FIG. 13, the mixing-air flow is injected via bores 226 which are located at least in the longitudinally directed edges 212, 214 of the top surface 210. This solution ensures effective cooling of the vortex generator, since the mixing-air flow issues at its extremities and thus passes completely around the inner walls of the element. **The mixing-air flow is fed here directly into the developing vortex, which leads to defined mixing within the main flow at supercritical blow-out rate.**

In FIG. 14, the mixing-air flow is injected via bores 227 which are located in the side surfaces 211 and 213, on the one hand in the region of the longitudinal edges 212 and 214, and on the other hand in the region of the connecting edge 216. This variant has a similar effect to that in FIG. 8 (bores 221) and in FIG. 13 (bores 226).

8. Claims 1-8, 10-12, 14, and 16 are rejected under 35 U.S.C. 102(b) as being clearly anticipated by Althaus et al. (US 5,513,982).

The patent to Althaus et al. '982 clearly discloses the recited vortex generator and method as seen in Figs. 1-8. The patent to Althaus et al. '982 clearly discloses the recited vortex generator and method as seen in Figs. 1-8 and as noted below (emphasis added). A walled flow duct 21 for a main flow (see flow arrow) is provided. Fig. 6 shows a side surface of the vortex generator including a plurality of outlet openings 22d of different geometrical configuration, namely the openings are at different special orientations with respect to the respective side surface of the vortex generator. The openings introduce a targeted secondary flow or axial impulse of fluid (see the flow arrows in Figs. 5-6) in the direction of the main flow into the vortex or vortices generated by the vortex generator (see Figs. 1 and 5-6). Countercurrent vortices located in the axis of the main flow are shown in Fig. 1.

More particularly, the patent to Althaus et al. '982 teaches a vortex generator and method, namely a combustion chamber in which a gaseous or liquid fuel is injected as a secondary flow into a gaseous, channelized main flow, the secondary flow having a considerably lower mass flow rate than the main flow. Cold flow strands can occur in

the main flow in combustion chambers, for example, as a result of the introduction of cooling air into the combustion air. Such flow strands can lead to inadequate combustion in the combustion zone. Measures must therefore be taken in order to mix combustion air, cooling air and fuel internally. A delta wing which is installed in a flow channel can be regarded as a vortex generator, in the broadest sense. If the incident flow strikes the tip of such a wing, then a stagnation region is formed downstream of the wing on the one hand and, on the other hand, as a result of the installed surface, the flow experiences a not inconsiderable drop in pressure. The arrangement of such a delta wing in a channel must be effected via aids such as webs, ribs or the like which have an adverse affect on the flow. Furthermore, problems arise, for example in a hot-gas flow, with the cooling of such elements. Such delta wings cannot be used as mixing elements for two or more flows. The mixing of a secondary flow with a main flow which is present in a channel is as a rule carried out by radial injection of the secondary flow into the channel. The impulse of the secondary flow is, however, so small that virtually complete mixing does not take place until after a distance of approximately 100 times the channel height.

Accordingly, one object of the invention is to provide a combustion chamber of the type mentioned initially which is equipped with a device by means of which longitudinal vortices can be produced, without any recirculation region, in the channel through which the flow passes. This is achieved according to the invention in that the main flow is passed via vortex generators, a plurality of which are arranged side by side over the width or circumference of the channel through which the flow passes,

preferably without any interspaces, and whose height is at least 50% of the height of the channel through which the flow passes or of that part of the channel associated with the vortex generators and in that the secondary flow is introduced into the channel in the immediate vicinity of the vortex generators. Using the new static mixer, which is represented by the three-dimensional vortex generators, it is possible to achieve extremely short mixing distances in the combustion chamber, with a low pressure loss at the same time. Coarse mixing of the two flows is completed even after one complete vortex revolution, while, as a consequence of turbulent flow and molecular diffusion processes, fine mixing takes place after a distance which corresponds to a few times the channel height. A vortex generator is distinguished by the fact, that it has three surfaces around which the flow passes freely and which extend in the flow direction, one of which forms the top surface and the two others form the side surfaces, that the side surfaces are flush with an identical channel wall and enclose the sweepback angle .alpha. between them, that the top surface has an edge which rests against the same channel wall as the side walls and runs transversely with respect to the channel through which the flow passes, and that the longitudinally directed edges of the top surface, which are flush with those longitudinally directed edges of the side surfaces which project into the flow channel, run at an incidence angle .theta. to the channel wall.

The advantage of such an element can be seen in its particular simplicity from every viewpoint. In production-engineering terms, the element, which comprises three walls around which the flow passes, is completely free of problems. The top surface can be assembled with the two side surfaces in very different ways. The fixing of the

element on flat or curved channel walls in the case of materials which can be welded can also be carried out by simple welding seams. From the fluid-dynamics point of view, the element has a very low pressure loss when flow passes around it and it produces vortices without any stagnation region. Finally, the element can be cooled in very different ways and using various means by means of its interior, which as a rule is hollow.

It is appropriate to select the ratio of the height h of the connecting edge of the two side surfaces with respect to the channel height H such that the pair of vortices produced occupies the complete channel height directly downstream of the vortex generator, or occupies the complete height of that channel part which is associated with the vortex generators. Since a plurality of vortex generators are arranged side by side, without any interspaces, over the width of the channel through which the flow passes, the vortices act over the complete channel cross section even at a short distance behind the vortex generators. It is sensible for the two side surfaces which enclose the sweepback angle .alpha. to be arranged symmetrically about an axis of symmetry. Vortices of identical spin are thus produced.

If the two side surfaces which enclose the sweepback angle .alpha. form a connecting edge with one another which is at least approximately sharp and forms a tip together with the longitudinal edges of the top surface, the blocking produces virtually no adverse effect on the flow cross section.

If the sharp connecting edge is the outlet-side edge of the vortex generator and it runs at right angles to that channel wall with which the side surfaces are flush, then the

avoidance of the formation of a wake region which is thus achieved is advantageous. Furthermore, a vertical connecting edge leads to side surfaces which are likewise at right angles to the channel wall, which gives the vortex generator the simplest possible shape and the shape which is most favorable in production-engineering terms.

If the axis of symmetry runs parallel to the channel axis and the connecting edge of the two side surfaces forms the downstream edge of the vortex generator while, in consequence, that edge of the top surface which runs transversely with respect to the channel through which the flow passes is the edge on which the channel flow initially acts, then two identical contrarotating vortices are produced on one vortex generator. A flow pattern of neutral spin is thus provided, in the case of which the rotation direction of the two vortices is such that the flow is rising in the region of the connecting edge.

For certain applications it is expedient if the incidence angle .theta. of the top surface and/or the sweepback angle .alpha. of the side surfaces are selected such that the vortex which is produced by the flow still breaks down in the region of the vortex generator. With the possible variation of the two angles, a simple aerodynamic stabilization means is available irrespective of the cross sectional shape of the channel through which the flow passes, which can be both broad and low as well as narrow and high, and can be provided with flat or curved channel walls.

Referring to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, in FIGS. 1, 5 and the actual channel, through which a main flow passes which is symbolized by a large arrow, is not illustrated. According to these figures, a vortex generator essentially comprises three

triangular surfaces around which the flow passes freely. These are a top surface 10 and two side surfaces 11 and 13. In their longitudinal extent, these surfaces run at specific angles in the flow direction.

In all the examples shown, the two side surfaces 11 and 13 are at right angles to the channel wall 21, it being noted that this is not essential. The side walls which comprise right-angled triangles are fixed by means of their longitudinal sides on this channel wall 21, preferably in a gas-tight manner. They are thus oriented such that they form a joint on their narrow sides enclosing a sweepback angle .alpha.. The joint is designed as a sharp connecting edge 16 and is likewise at right angles to that channel wall 21 with which the side surfaces are flush. The two side surfaces 11, 13 which enclose the sweepback angle .alpha. are symmetrical in shape, size and orientation and are arranged on both sides of an axis of symmetry 17 (FIGS. 3b, 4b). This axis of symmetry 17 is in the same direction as the channel axis.

The top surface 10 has an edge 15, which is constructed with a very sharp tip, runs transversely with respect to the channel through which the flow passes and rests against the same channel wall 21 as the side walls 11, 13.

The longitudinally directed edges 12, 14 of the top surface 10 are flush with those longitudinally directed edges of the side surfaces which project into the flow channel. The top surface is positioned at an incidence angle .theta. with respect to the channel wall 21. The longitudinal edges 12, 14 come together at a tip 18 with the connecting edge 16.

The vortex generator can, of course, also be provided with a base surface by means of which it is fastened to the channel wall 21 in a suitable manner. However, such a base surface has no connection with the method of operation of the element.

In FIG. 1, the connecting edge 16 of the two side surfaces 11, 13 forms the downstream edge of the vortex generator. That edge 15 of the top surface 10 which runs transversely with respect to the channel through which the flow passes is thus the edge on which the channel flow initially acts.

The method of operation of the vortex generator is as follows: while the flow is passing around the edges 12 and 14, **the main flow is converted into a pair of contrarotating vortices**. Their vortex axes lie on the axis of the main flow. The number of turns and the location of the vortex breakdown, to the extent that the latter is desired at all, are determined by suitable selection of the incidence angle .theta. and of the sweepback angle alpha. As the angles increase, the vortex intensity and the number of turns increases and the location of the vortex breakdown moves upstream as far as the region of the vortex generator itself. Depending on the application, these two angles .theta. and .alpha. are predetermined by design characteristics and by the process itself. Only the length L of the element (FIG. 3b) and the height h of the connecting edge 16 (FIG. 3a) need then still be matched.

In FIGS. 3a and 4a, in which the channel through which the flow passes is designated by 20, it can be seen that the vortex generator can have different heights with respect to the channel height H. As a rule, the height h of the connecting edge 16 is selected for the channel height H such that the vortex which is produced reaches a

magnitude even immediately downstream of the vortex generator such that the complete channel height H is occupied, which leads to a uniform speed distribution in the cross section acted on. A further criterion which can influence the selectable ratio h/H is the pressure drop which occurs while the flow is passing around the vortex generator. It is self-evident that the pressure loss coefficient also rises with a larger ratio h/H.

In contrast to FIG. 1, the sharp connecting edge 16 in FIG. 2 is that point on which the channel flow acts initially. The element is rotated through 180 degrees. As can be seen from the illustration, the two contrarotating vortices have changed their direction of rotation.

FIGS. 3a-c show how a plurality of vortex generators, in this case three, are arranged side by side without interspaces over the width of the channel 20 through which the flow passes. In this case, the channel 20 has a rectangular shape, but this is not significant to the invention.

FIG. 4 shows a design variant having two full vortex generators and two half vortex generators which are adjacent thereto on both sides. With the same channel height H and the same incidence angle .theta. of the top surface 10 as in FIGS. 3a-c, the elements differ especially as a result of their greater height h. With a constant incidence angle, this necessarily leads to a greater length L of the element and, in consequence, also--because of the same spacing--to a smaller sweepback angle .alpha.. In comparison with FIG. FIGS. 3a-c, the vortices which are produced have a lower spin intensity but completely occupy the channel cross section within a shorter

interval. If vortex breakdown is intended in both cases, for example for stabilizing the flow, this will take place later in the case of the vortex generator according to FIGS. 4a-c than in the case of that according to FIGS. 3a-c.

The channels which are illustrated in FIGS. 3a-c and 4a-c represent rectangular combustion chambers. Once again it should be noted that the shape of the channel through which the flow passes is not significant for the method of operation of the invention. Instead of the rectangle shown, the channel could also comprise an annular segment, that is to say the walls 21a and 21b would be curved. The above statement that the side surfaces are at right angles to the channel wall must, of course, be made relative in such a case. The significant factor is that the connecting edge 16, which lies on the line of symmetry 17, is at right angles to the corresponding wall. In the case of annular walls, the connecting edge 16 would thus be aligned radially, as is illustrated in FIG. 7.

FIGS. 7 and 8 show in simplified form a combustion chamber having a channel 20 through which the flow passes in an annular shape. An identical number of vortex generators are in each case arranged in a row in the circumferential direction on both channel walls 21a and 21b such that the connecting edges 16 of two opposite vortex generators lie on the same radial. If identical heights h are specified for opposite vortex generators, then FIG. 7 shows that the vortex generators have a smaller sweepback .alpha. on the inner channel annulus 21b. In the longitudinal section in FIG. 8 it can be seen that this could be compensated for by a larger incidence angle .theta. if vortices having identical spin are desired in the inner and outer annulus cross section. In the

case of this solution, as is indicated in FIG. 7, two pairs of vortices are produced which each have relatively small vortices, which leads to a shorter mixing length. In the case of this design, the fuel could be introduced into the main flow in accordance with the methods in FIG. 5 or 6, which will be described later.

In FIGS. 3a-c and 4a-c which have already been described, two flows are mixed with one another with the aid of the vortex generators 9. The main flow, in the form of combustion air--or combustion gas depending on the type of combustion chamber--attacks the transversely directed leading edges 15 in the direction of the arrow. The secondary flow in the form of a fuel which is, for example, liquid has a considerably lower mass flow rate than the main flow. It is introduced into the main flow at right angles, in the immediate vicinity of the vortex generators.

According to FIG. FIGS. 3a-c, this injection is effected via individual holes 22a which are incorporated in the wall 21a. The wall 21a is that wall on which the vortex generators are arranged. The holes 22a are located on the line of symmetry 17, downstream behind the connecting edge 16 of each vortex generator. In the case of this configuration, the fuel is introduced into the already existing large-scale vortices.

FIG. 4 shows a design variant of a combustion chamber in the case of which the secondary flow is likewise injected via wall holes 22b. The latter are located downstream of the vortex generators in that wall 21b on which the vortex generators are not arranged, that is to say on the wall which is opposite the wall 21a. The wall holes 22b are in each case incorporated centrally between the connecting edges 16 of two adjacent vortex generators, as can be seen in FIG. 4b. In this way, the fuel passes into

the vortices in the same manner as in the design according to FIGS. 3a-c. However, the difference is that it is no longer mixed into the vortices of a pair of vortices produced by an identical vortex generator but into in each case one vortex of two adjacent vortex generators. Since the adjacent vortex generators are, however, arranged without any interspace and produce pairs of vortices with the same direction of rotation, the injection methods according to FIGS. 3a-c and 4a-c have the same effect.

FIGS. 5 and 6 show further possible forms for the introduction of the secondary flow into the main flow. Here, the secondary flow is introduced into the hollow interior of the vortex generator through the channel wall 21, via means which are not shown.

According to FIG. 5, the secondary flow is injected into the main flow via a wall hole 22e, the hole being arranged in the region of the tip 18 of the vortex generator.

In FIG. 6, the injection is effected via wall holes 22d, which are located in the side surfaces 11 and 13, on the one hand in the region of the longitudinal edges 12 and 14 and on the other hand in the region of the connecting edge 16.

Finally, FIGS. 9 to 14 show different installation possibilities for the vortex generators. As in FIG. 7, the partial view in FIG. 9 shows an annular channel 20 in the case of which an identical number of vortex generators 9 are arranged in a row in the circumferential direction both on the outer annular wall 21a and on the inner annular wall 21b. However, in contrast to FIG. 7, the connecting edges 16 of in each case two opposite vortex generators are here offset with respect to one another by half of the spacing. This arrangement offers the possibility of increasing the height h of the individual element. The vortices which are produced are combined with one another

downstream of the vortex generators, which on the one hand further improves the mixing quality and on the other hand leads to a longer life of the vortex.

In the partial view according to FIG. 10, the annular channel is segmented by means of radially running ribs 23. In the circular-ring segments formed in this manner, in each case one vortex generator 9 is arranged on the ribs 23. In the case shown, the two vortex generators are designed such that they occupy the entire channel height. This solution simplifies the fuel supply, which can be carried out through the ribs, which are designed hollow. There is thus no adverse effect on the flow as a result of centrally arranged fuel lances.

In the partial view according to FIG. 11, in addition to the side vortex generators as in the case of FIG. 10, vortex producers are also fitted on the annular walls 21a and 21b. The connecting edges of the side elements run at half the height of the channel, that of the upper and of the lower elements on a radial at half the segment width. This is a very good solution in terms of the method of operation. In contrast to the variant according to FIG. 10, the elements here cannot occupy the entire channel height. It must therefore not be forgotten that the cooling which is possibly required is structurally complex since it is not possible to supply cooling air for the side elements directly from the annular walls.

As a remedy for this, in contrast to FIG. 11, the vortex generators 9 in FIG. 12 are arranged eccentrically on the radial ribs 23 and on the annular walls 21a, 21b. In this case, one side surface of each vortex generator in each case rests against a corner of the circular-ring segment, from where the side vortex generators can also be supplied

with cooling air from the radially outer annular wall 21a on the one side and from the inner annular wall 21b on the other side.

In yet another design according to FIG. 13, likewise with respect to a simple cooling capability, the vortex generators 9 are arranged directly in the segment corners in each segment of the circular-ring channel.

In the plan view according to FIG. 14, the possibility can be seen of not accommodating the vortex generators in the same plane. Of the vortex generators which are arranged in a row with their side walls against a channel wall, two adjacent elements are in each case offset with respect to one another in the longitudinal direction of the channel 20. In the case of this variant, vortex overlapping takes place in the circumferential direction. This is a measure which is suitable for optimizing the combination of pairs of vortices. Different geometries can be selected for the vortex generators, which are connected one behind the other. Furthermore, the arrangement in different planes of the channel has a favorable influence against the building up of acoustic oscillations.

FIGS. 15a-c show the secondary flow additionally being introduced centrally in a mixed arrangement of the variants dealt with in FIGS. 6, 11 and 14. The fuel, as a rule oil, is injected via a central fuel lance 24 whose mouth is located downstream of the vortex generators 9, in the region of their tips 18. In the case of a rectangular channel which, of course, could just as well be a circular-ring segment, vortex generators of different geometry are used on one side. Furthermore, the successive vortex generators in the "circumferential direction" are slightly offset with respect to one another. This is,

for example, to create sufficient space for the lance. Finally, the partial injection of the secondary flow is effected via wall holes in the side surfaces of the vortex generators, as is indicated by arrows. The gas supply is effected via gas lines 25 which run along the wall. Using the configuration shown, such a combustion chamber would be well suited for dual operation with premixing combustion. In the case of a pressure drop coefficient of 3, good mixing is achieved even after approximately three times the channel height. The mixture is ignited 26 at the point at which the vortex breaks down. For additional flame stabilization, a diffusor 27 is arranged in the plane behind the mixing zone on which the ignition takes place. The good temperature distribution, which is achieved as a result of the mixing elements, downstream of the vortex generators avoids the risk of surges, which, without the measure, are possible in the case of cooling air being introduced, as mentioned initially, into the combustion air.

The combustion chamber just described could furthermore be a self-igniting afterburning chamber downstream of a high-temperature gas turbine. The high energy content of its exhaust gases makes self-ignition possible. A precondition for optimization of the combustion process, especially with respect to minimizing emissions, is effective, rapid mixing of the hot-gas flow with the injected fuel.

On the basis of a vortex generator configuration according to FIGS. 15a-c, with central injection of the fuel via a lance, the vortex generators are designed such that recirculation zones are avoided to a very large extent. In consequence, the dwell time of the fuel particles in the hot zones is very short. The injected fuel is dragged along by the vortices and is mixed with the main flow. It follows the helical course of the vortices and

is distributed uniformly and finely in the chamber downstream of the vortices. This reduces the risk--in the case of the initially mentioned radial injection of fuel into a flow without vortices--of jets striking against the opposite wall and forming so-called "hot spots".

Since the main mixing process takes place in the vortices and is largely insensitive to the injection impulse of the secondary flow, the fuel injection can be kept flexible and can be matched to other boundary conditions. The same injection impulse can thus be maintained throughout the load range. Since the mixing is governed by the geometry of the vortex generators and not by the machine load, the gas turbine power in the case of the example, the afterburner configured in this way operates in an optimum manner even in partial-load conditions. The combustion process is optimized by matching the ignition delay time of the fuel and the mixing time of the vortices, which ensures that emissions are minimized.

Furthermore, the effective mixing produces a good temperature profile over the cross section through which the flow passes and, furthermore, reduces the possibility for thermo-acoustic instability to occur. Just by their presence, the vortex generators act as a damping measure against thermo-acoustic oscillations.

FIGS. 16 and 17 show a plan view of a design variant of the vortex generator and a front view of its arrangement in a circular channel. The two side surfaces 11 and 13 which enclose the sweepback angle .alpha. have a different length. This means that the top surface 10, having an edge 15a which runs obliquely with respect to the channel through which the flow passes, rests against the same channel wall as the side walls.

The vortex generator then has a different incidence angle .theta., of course, over its width. Such a variant has the effect that vortices having a different intensity are produced. For example, it is thus possible to act on a spin which adheres to the main flow. Alternatively, however, a spin, as is indicated in FIG. 17, can be imposed, downstream of the vortex generators, on the originally spin-free main flow, by means of the different vortices.

9. Claims 1-12, 14, and 16 are rejected under 35 U.S.C. 102(b) as being clearly anticipated by Althaus et al. (US 5,518,311).

The patent to Althaus et al. '311 clearly discloses the recited vortex generator and method as seen in Figs. 1-14 and as noted below (emphasis added). A walled flow duct 21 for a main flow (see flow arrow) is provided. Figs. 13-14 show a side surface of the vortex generator including a plurality of outlet openings 12 of different geometrical configuration, namely the openings are at different special orientations with respect to the respective side surface of the vortex generator. The openings introduce a targeted secondary flow or axial impulse of fluid (see the flow arrows in Figs. 13-14) in the direction of the main flow into the vortex or vortices generated by the vortex generator (see Figs. 1 and 13-14). Countercurrent vortices located in the axis of the main flow are shown in Fig. 1. Fig. 9 shows the openings for fluid injection can be formed as a slit 22e.

More particularly, the patent to Althaus et al. '311 teaches a vortex generator and method, <u>namely a mixing chamber in which a gaseous secondary flow is introduced into</u>

a gaseous, ducted main flow, the secondary flow having a substantially smaller mass flow than the main flow. Cold streaks, which occur for example due to cooling air being fed into the combustion air, can be found in the main flow in combustion chambers. Such streaks can lead to inadequate burn-out in the combustion zone. Measures have therefore to be taken in order to mix the combustion air and cooling air thoroughly. The mixing of a secondary flow with a main flow present in a duct takes place, as a rule, by radial introduction of the secondary flow into the duct. The momentum of the secondary flow, however, is so small that even almost complete mixing only takes place after a distance of approximately 100 duct heights.

Accordingly, one object of the invention is to provide a mixing chamber, of the type mentioned at the beginning, with a novel appliance by means of which longitudinal vortices without a recirculation region can be generated in the duct through which flow takes place. This is achieved in accordance with the invention wherein the main flow is guided via vortex generators, of which a plurality are arranged adjacent to one another and preferably without intermediate spaces over the width or the periphery of the duct through which flow takes place, the height of the vortex generators being at least 50% of the height of the duct through which flow takes place or of the height of the duct part associated with the vortex generator, and wherein the secondary flow is led into the duct in the immediate region of the vortex generators. Using the novel static mixer, which is represented by the three-dimensional vortex generators, it is possible to achieve extraordinarily short mixing distances in the mixing chamber with a simultaneously low pressure loss. Rough mixing of the two flows has already been

completed after one full rotation of the vortex whereas fine mixing due to turbulent flow takes place after a distance which corresponds to just a few duct heights. A vortex generator according to the present invention has three surfaces around which flow takes place freely, which surfaces extend in the flow direction, one of them forming the top surface and the others forming the side surfaces, wherein the side surfaces abut the same duct wall and enclose the acute angle .alpha. between them, wherein a top surface edge extending transverse to the duct through which flow takes place is in contact with the same duct wall as the side walls, and wherein the longitudinally directed edges of the top surface, which abut the longitudinally directed edges of the side surfaces protruding into the flow duct, extend at an angle of incidence .THETA. to the duct wall.

The advantage of such a vortex generator may be seen in its particular simplicity in every respect. The element, which consists of three walls around which flow takes place, is completely unproblematic from the point of view of manufacture. The top surface can be joined to the two side surfaces in various ways. The fixing of the element onto flat or curved duct walls can also take place by means of simple welds in the case of weldable materials. From the point of view of fluid mechanics, the element has a very low pressure loss when flow takes place around it and it generates vortices without a dead water region. Finally, the element can be cooled in different ways and with various means because of its generally hollow internal space.

It is useful to select the ratio between the height h of the connecting edge of the two side surfaces and the duct height H in such a way that the vortex generated fills the

complete duct height, or the complete height of the duct part associated with the vortex generator, immediately downstream of the vortex generator. The large-scale vortices generated ensure that a similar distribution is present in every plane behind the vortex generator.

Because a plurality of vortex generators are arranged adjacent to one another without intermediate spaces over the width of the duct through which flow takes place, the complete duct cross section is already being fully acted on by the vortices shortly behind the vortex generators.

It is useful for the two side surfaces enclosing the acute angle .alpha. to be arranged symmetrically about an axis of symmetry. Equal-swirl vortices are generated by this means.

If the two side surfaces enclosing the acute angle .alpha. form between them an at least approximately sharp connecting edge which, together with the longitudinal edges of the top surface, form a point, the flow cross section is almost unimpaired by blockage.

If the connecting edge is the outlet edge of the vortex generator and if it extends at right angles to the duct wall which the side surfaces abut, the non-formation of a wake region is advantageous. In addition, a vertical connecting edge leads to side surfaces which are likewise at right angles to the duct wall. This provides the vortex generator with the simplest possible shape and the shape most favorable for manufacture.

If the axis of symmetry extends parallel to the duct axis and the connecting edge of the two side surfaces forms the downstream edge of the vortex generator whereas the top surface edge extending transverse to the duct through which flow takes place is, in consequence, the edge which the duct flow meets first, two equal and opposing vortices are generated on one vortex generator. A neutral-swirl flow pattern is present in which the direction of rotation of the two vortices rises in the region of the connecting edge.

For certain applications, it is expedient for the angle of incidence .THETA. of the top surface and/or the acute angle .alpha. of the side surfaces to be selected in such a way that the vortex generated by the flow has already broken down in the region of the vortex generator. The possible variation of the two angles provides a simple means of aerodynamic stabilization, independent of the cross sectional shape of the duct through which flow takes place. The duct can be either wide and low or narrow and high and can be provided with flat or curved duct walls.

FIGS. 1 and 2 do not show the actual duct through which the main flow (symbolized by the large arrow) takes place. As shown in these figures, a vortex generator consists essentially of three triangular surfaces around which flow takes place freely. These are a top surface 10 and two side surfaces 11 and 13. In their longitudinal extent, these surfaces extend at certain angles in the flow direction.

In all the examples shown, the two side surfaces 11 and 13 are at right angles to the duct wall 21 but it should be noted that this is not imperative. The side walls, which consist of right-angle triangles, are fixed with their long sides on the duct wall 21,

preferably in a gas-tight manner. They are oriented in such a way that they form a joint on their short sides and enclose an acute angle .alpha.. The joint is designed as a sharp connecting edge 16 and is also at right angles to the duct wall 21 which the side surfaces abut. The two side surfaces 11, 13 enclosing the acute angle .alpha. are symmetrical in shape, size and orientation and are arranged on both side of an axis of symmetry 17. This axis of symmetry 17 is parallel to the duct axis.

An edge 15 of the top surface 10, which has a very sharp configuration and extends transverse to the duct axis through which flow takes place, is in contact with the same duct wall 21 as the side walls 11, 13. The longitudinally directed edges 12, 14 of the top surface 10 abut the longitudinally directed edges of the side surfaces 11, 13 protruding into the flow duct. The top surface 10 extends at an angle of incidence .THETA. to the duct wall 21. Its longitudinal edges 12, 14, together with the connecting edge 16, form a point 18.

The vortex generator 9 can also, of course, be provided with a bottom surface by means of which it is fastened to the duct wall 21 in a suitable manner. Such a bottom surface, however, has no connection with the mode of operation of the element.

In FIG. 1, the connecting edge 16 of the two side surfaces 11, 13 forms the downstream edge of the vortex generator. The edge 15 of the top surface 10, extending transverse to the duct axis through which flow takes place is therefore the edge which the duct flow meets first.

<u>The mode of operation of the vortex generator is as follows. When flow takes place around the edges 12 and 14, the main flow is converted into a pair of opposing</u>

vortices whose axes are located in the axis of the main flow. The swirl number and the location of vortex breakdown, where the latter is desirable at all, are determined by appropriate selection of the angle of incidence .THETA. and the acute angle .alpha.. With increasing angles, the vortex strength and the swirl number are increased and the location of the vortex breakdown moves upstream into the region of the vortex generator itself. These two angles .THETA. and .alpha. are specified, depending on the application, by design requirements and by the process itself. It is then only necessary to match the height h of the connecting edge 16 (FIG. 3a).

In FIGS. 3a and 4a, in which the duct through which flow takes place is indicated by 20, it may be recognized that the vortex generator can have a different height relative to the duct height H. In general, the height h of the connecting edge 16 will be matched to the duct height H in such a way that the vortex generated has already reached such a size immediately downstream of the vortex generator that the complete duct height H is filled. This leads to an even velocity distribution in the cross section acted on by the vortex generator. A further criterion, which can have an influence on the ratio h/H to be selected, is the pressure drop which occurs when flow takes place around the vortex generator. It is obvious that as the ratio of h/H increases, the pressure loss coefficient will also increase.

In contrast to FIG. 1, the sharp connecting edge 16 in FIG. 2 is the position which the duct flow meets first. The element 9 shown in FIG. 2 is rotated by 180 degrees compared to the orientation shown in FIG. 1. As may be recognized from the representation, the two opposing vortices have changed their direction of rotation.

FIG. 3b shows how a plurality of vortex generators, in this case three, are arranged adjacent to one another without intermediate spaces over the width of the duct through which flow takes place. In this case, the duct 20 has a rectangular shape but this, however, is not essential to the invention.

FIGS. 4a-c show a variant with two complete vortex generators and, on both sides of them, two half vortex generators. For the same duct height H and the same angle of incidence .THETA. of the top surface 10 as in FIGS. 3a-c, the elements differ, in particular, because of their greater height h. For the same angle of incidence, this necessarily leads to a larger length L of the element and in consequence--because the pitch is the same--it also leads to a smaller angle .alpha.. Compared with FIGS. 3a--c, the vortices generated will have less swirl but will completely fill the duct cross section within a shorter interval. If vortex breakdown is intended in both cases--in order to stabilize the flow, for example--this will take place later in the case of the vortex generator of FIGS. 4a-c than it does with that of FIGS. 3a-c.

The ducts shown in FIGS. 3a-c and 4a-c represent rectangular mixing chambers. It should again be noted that the shape of the duct through which flow takes place is not essential to the mode of operation of the invention. Instead of the rectangle shown, the duct could also be an annular segment, i.e. the walls 21a and 21b would be curved. The above statement that the side surfaces are at right angles to the duct wall must, of course, be considered in a relative manner in such a case. The essential point is that the connecting edge 16 located on the line of symmetry 17 is at right angles to the

corresponding wall. In the case of annulus walls, the connecting edge 16 would therefore be directed radially, as is represented in FIG. 5.

FIGS. 5 and 6 show, in a simplified manner, a mixing chamber with an annular duct 20 through which flow takes place. This annular chamber could, for example, be the annular combustion chamber of a gas turbine. An equal number of vortex generators are arranged in a row in the peripheral direction on each of the two duct walls 21a and 21b in such a way that the connecting edges 16 of two opposite vortex generators are located in the same radial. If the same heights h are assumed for opposite vortex generators, it may be seen from FIG. 5 that the vortex generators have a smaller acute angle .alpha. on the inner duct annulus 21b. It may be recognized from the longitudinal section in FIG. 6 that compensation could be provided for this by means of a larger angle of incidence .THETA. if vortices of equal swirl are desired in the inner and outer annulus cross sections. In this solution, as is indicated in FIG. 5, two vortex pairs with smaller vortices are generated in each case and this leads to a shorter mixing length. The secondary flow, for example cooling air, could be fed into the main flow in this configuration in accordance with the methods of FIGS. 8 to 14, which are described later.

Two flows are mixed together with the aid of the vortex generators 9 in FIGS. 3a-c and 4a-c, which have already been described. The main flow in the form of combustion air--or combustion gas depending on the type of combustion chamber--attacks the transversely directed inlet edges 15 in the direction of the arrow. The

secondary flow in the form of cooling air has a substantially smaller mass flow than the main flow. It is fed into the main flow in the immediate region of the vortex generators.

As shown in FIG. 3b, this introduction of air takes place by means of individual holes 22a which are applied to the wall 21a. The wall 21a is the wall on which the vortex generators are arranged. The holes 22a are located on the line of symmetry 17 downstream behind the connecting edge 16 of each vortex generator. In this configuration, the cooling air is inserted into the large-scale vortex which already exists.

FIG. 4b shows an embodiment variant of a mixing chamber in which the secondary flow is likewise introduced via wall holes 22b. The latter are located downstream of the vortex generators in the wall 21b on which the vortex generators are not arranged, i.e. on the wall opposite to the wall 21a. The wall holes 22b are respectively applied between the connecting edges 16 of two adjacent vortex generators, as may be seen from FIG. 4b. In this way, the cooling air passes into the vortex in the same way as in the embodiment of FIG. 3b. There is, however, the difference that it is no longer mixed into the vortex of a vortex pair generated by the same vortex generator but into one vortex each of two adjacent vortex generators. Because the adjacent vortex generators are arranged without an intermediate space and generate vortex pairs with the same direction of rotation, however, the introduction arrangements of FIGS. 3b and 4b have the same effect.

The partial view in FIG. 7, like FIG. 5, shows an annular duct 20 in which an equal number of vortex generators 9 are arranged in a row in the peripheral direction both on the outer annulus wall 21a and on the inner annulus wall 21b. As a departure

from FIG. 5, however, the connecting edges 16 of each two opposite vortex generators are offset relative to one another by half a pitch. This arrangement offers the possibility of increasing the height h of the individual elements. Downstream of the vortex generators, the vortices generated are combined with one another which, on the one hand, further improves the mixing quality and, on the other, leads to an increased vortex life.

FIGS. 8 to 14 show further possible ways of feeding the secondary flow into the main flow, cold cooling air to be mixed with hot combustion air or combustion gases being, for example, involved.

As shown in FIG. 8, the cooling air is introduced by means of wall holes 22c--in addition to the holes 22a already described downstream of the vortex generators--which wall holes 22c are located immediately adjacent to and in the longitudinal extent of the side walls 11, 13 in the same wall 21a on which the vortex generators are arranged. Feeding the secondary flow through the wall holes 22c provides additional momentum to the vortices generated and this increases their life.

As shown in FIGS. 9 and 10, the cooling air is introduced, on the one hand, by means of a slot 22e or by means of wall holes 22f. These are located in the same annulus wall 21a on which the vortex generators are arranged and immediately before and in the longitudinal extent of the edge 15, of the top surface 10, extending transverse to the duct through which flow takes place. The geometry of the wall holes 22f or of the slot 22e is selected in such a way that the cooling air is introduced at a certain injection

angle into the main flow and flows around the following vortex generator as a protective film against the hot main flow.

In the examples described below, the secondary flow is fed through the duct wall 21a into the hollow internal space of the vortex generator via means which are not shown.

As shown in FIG. 11, the cooling air is introduced via wall holes 22g which are located within the top surface 10 immediately behind and in the longitudinal extent of the edge 15 extending transverse to the duct through which flow takes place. The cooling of the vortex generator takes place externally rather than internally in this case. The emerging secondary flow forms a protective layer when it flows around the top surface 10 and screens the latter from the hot main flow.

As shown in FIG. 12, the cooling air is introduced via wall holes 22h which are arranged within the top surface 10 in a row along the line of symmetry 17. The duct walls are particularly well protected from the hot main flow by means of this variant because the cooling air is initially guided on the outer periphery of the vortex.

As shown in FIG. 13, the cooling air is introduced via wall holes 22j which are located in the longitudinally directed edges 12, 14 of the top surface 10. This solution ensures good cooling of the vortex generators because the cooling air emerges at the extremities and therefore flushes completely round the inner walls of the element. The secondary flow is put directly into the resulting vortex in this case and this leads to defined flow relationships.

In FIG. 14, the introduction of the air takes place via wall holes 22d, which are located in the side walls 11 and 13 in the region of the longitudinal edges 12 and 14, on the one hand, and in the region of the connecting edge 16, on the other. This variant has a similar effect to that produced by using the holes 22a in FIG. 8 and using the holes 22j in FIG. 11.

If, for example, the mixing chamber is a combustion chamber, the fuel--oil as a rule--is introduced via a central fuel lance 24 whose opening is located downstream of the vortex generators 9 in the region of their point 18, as shown in FIG. 6. The introduction of the cooling air takes place in two ways in this example. On the one hand, as is indicated by arrows, it is introduced via wall holes in the vortex generators themselves in accordance with one of the methods shown in FIGS. 11 to 14, and on the other, it is introduced via wall holes 22a in the duct wall 21b, it being possible to supply these wall holes by means of a ring main.

If a vortex generator configuration as shown in FIG. 6 with central introduction of the fuel via a lance 24 is taken as a basis, the vortex generators 9 are designed in such a way that recirculation zones are substantially avoided. The fuel introduced is entrained by the vortices and mixed with the main flow. It follows the helical path of the vortex and is evenly and finely distributed in the chamber downstream of the vortices.

As a departure from previously shown vortex generators, the two side surfaces 11, 13, of the vortex generator 9, enclosing the acute angle .alpha. could also have different lengths L. In this case, the top surface 10 with an edge 15 extending obliquely to the duct 20 through which flow takes place would be in contact with the same duct

wall 21 as the side walls and would have a different angle of incidence .THETA. over the width of the vortex generator. Such a variant has the effect that vortices with different strengths are generated. A swirl adhering to the main flow can, for example, be acted upon by this means. On the other hand, however, swirl can be imposed, by the different vortices, downstream of the vortex generators on the originally swirl-free main flow.

Claim Rejections - 35 USC § 103

10. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

11. This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

12. Claim 9 is rejected under 35 U.S.C. 103(a) as being unpatentable over Schulte-Werning (US 5,735,126), Althaus et al. (US 5,518,311), or Althaus et al. (US 5,513,982).

Althaus et al. (US 5,513,982) does not show the outlet opening in a slit shape and assuming, arguendo, that Schulte-Werning (US 5,735,126) or Althaus et al. (US 5,518,311) do not suggest the slit shaped opening associated with the vortex generator, it is noted that one of ordinary skill in the art would have recognized that an opening in a circular shape or an opening in a slit shape are all well known types of injection openings used in the mixing art, and that such opening configurations are generally alternative mechanical structures used for injection openings/apertures of the type shown in the prior art to Althaus et al. and as claimed by applicant. Moreover, applicant's specification at page 8 does not indicate that the type of opening (circular or slit type) employed solves any stated problem or produces any new or unexpected result. Accordingly, it can be concluded that the particular shape of the injection opening employed on the surface(s) of the vortex generators in Althaus et al. (US 5,513,982), Schulte-Werning (US 5,735,126) or Althaus et al. (US 5,518,311) would have been a matter of obvious design choice to one of ordinary skill in the art and thus does not serve to patentably distinguish the claimed invention over the prior art. *In re Kuhle*, 526 F.2d 553, 188 USPQ 7 (CCPA 1975).

Response to Amendment

13. Applicant's arguments filed 12 OCT 2005 have been fully considered but they are not deemed to be persuasive.

Applicant is reminded that "[a] claim is anticipated only if each and every element as set forth in the claim is found, either expressly or inherently described, in a single prior art reference." *Verdegaal Bros. v. Union Oil Co. of California*, 814 F.2d 628, 631, 2 USPQ2d 1051, 1053 (Fed. Cir. 1987). "The identical invention must be shown in as complete detail as is contained in the ... claim." *Richardson v. Suzuki Motor Co.*, 868 F.2d 1226, 1236, 9 USPQ2d 1913, 1920 (Fed. Cir. 1989). The elements must be arranged as required by the claim, but this is not an ipsissimis verbis test, i.e., identity of terminology is not required. *In re Bond*, 910 F.2d 831, 15 USPQ2d 1566 (Fed. Cir. 1990).

Turning to the rejection of the claims under 35 U.S.C. § 102(b), it is noted that the terminology in a pending application's claims is to be given its broadest reasonable interpretation (*In re Zletz*, 893 F.2d 319, 321, 13 USPQ2d 1320, 1322 (Fed. Cir. 1989)) and limitations from a pending application's specification will not be read into the claims (*Sjolund v. Musland*, 847 F.2d 1573, 1581-82, 6 USPQ2d 2020, 2027 (Fed. Cir. 1988)). Anticipation under 35 U.S.C. § 102(b) is established only when a single prior art reference discloses, either expressly or under the principles of inherency, each and every element of a claimed invention. *See Constant v. Advanced Micro-Devices. Inc.*, 848 F.2d 1560, 1570, 7 USPQ2d 1057, 1064 (Fed. Cir.), cert. denied, 488 U.S. 892 (1988); *RCA Corp. v. Applied Digital Data Sys., Inc.*, 730 F.2d 1440, 1444, 221 USPQ

385, 388 (Fed. Cir. 1984). Moreover, anticipation by a prior art reference does not require either the inventive concept of the claimed subject matter or the recognition of properties that are inherently possessed by the prior art reference. *Verdegaal Brothers Inc. v. Union Oil co. of California*, 814 F.2d 628, 633, 2 USPQ2d 1051, 1054 (Fed. Cir. 1987), cert. denied, 484 U.S. 827 (1987). A prior art reference anticipates the subject matter of a claim when that reference discloses each and every element set forth in the claim (*In re Paulsen*, 30 F.3d 1475, 1478-79, 31 USPQ2d 1671, 1673 (Fed. Cir. 1994) and *In re Spada*, 911 F.2d 705, 708, 15 USPQ2d 1655, 1657 (Fed. Cir. 1990)); however, the law of anticipation does not require that the reference teach what Applicant is claiming, but only that the claims "read on" something disclosed in the reference. *Kalman v. Kimberly-Clark Corp.*, 713 F.2d 760, 772, 218 USPQ 781, 789 (Fed. Cir. 1983), cert. denied, 465 U.S. 1026 (1984) (and overruled in part on another issue), *SRI Intel v. Matsushita Elec. Corp. Of Am.*, 775 F.2d 1107, 1118, 227 USPQ 577, 583 (Fed. Cir. 1985). Also, a reference anticipates a claim if it discloses the claimed invention such that a skilled artisan could take its teachings in combination with his own knowledge of the particular art and be in possession of the invention. See *In re Graves*, 69 F.3d 1147, 1152, 36 USPQ2d 1697, 1701 (Fed. Cir. 1995), cert. denied, 116 S.Ct. 1362 (1996), quoting from *In re LeGrice*, 301 F.2d 929, 936, 133 USPQ 365, 372 (CCPA 1962).

With respect to the applied prior art under 35 U.S.C. § 102(b), the examiner has explicitly demonstrated how the references disclose each and every element set forth in

the claims and how the pending claims read on the disclosures of the references, hence the rejections are considered proper.

With regard to the apparatus claims, all the recited structure is shown and disclosed by the applied prior references. The applied prior art is drawn to vortex generators placed in flow duct as set forth in the preamble of claim 1. However, Applicant predicates patentability of claim 1 on the materials processed by the vortex generators and the behavior of the said materials (such as the flows and vortices). Such arguments are not compelling, since a recitation with respect to the material intended to be worked upon by a claimed apparatus (the flows and vortices in this instance) does not impose any structural limitations upon the claimed apparatus, which differentiates it from a prior art apparatus satisfying the structural limitations of that claimed. See *Ex parte Masham*, 2 USPQ2d 1647, 1648 (Bd. App. 1987). Also see *In re Rishoi*, 197 F.2d 342, 344, 94 USPQ 71, 72 (CCPA 1952); and *In re Young*, 75 F.2d 996, 997, 25 USPQ 69, 70 (CCPA 1935). Accordingly, the recitation of what particular substances and the behavior of those substances in the apparatus are not germane to the patentability of the apparatus itself. Since all of the claimed elements are met by the prior art applied above under 35 U.S.C 102, 103, the rejections are considered proper.

"Expressions relating the apparatus to contents thereof during an intended operation are of no significance in determining patentability of the apparatus claim." *Ex parte Thibault*, 164 USPQ 666, 667 (Bd. App. 1969). Furthermore, "[i]nclusion of material or article worked upon by a structure being claimed does not impart

patentability to the claims." *In re Young*, 75 F.2d 966, 25 USPQ 69 (CCPA 1935) (as restated in *In re Otto*, 312 F.2d 937, 136 USPQ 458, 459 (CCPA 1963)).

However, for purposes of further prosecution or appeal, the examiner will discuss the issue as to whether the devices of Schulte-Werning, Althaus et al. '982 or '311 are capable of performing the functions set forth in lines 11-13 of claim 1 as amended, and as argued by Applicant.

Contrary to Applicant's assertion, is not necessary that the prior art explicitly disclose a such a function. All that is required is evidence that the device of the prior art is capable of establishing performing the function. As noted above, there is ample reason to believe that the vortex generators of the prior art are capable of being used to achieve the acts or functions included in the claims, including introducing a targeted secondary flow in the core flow of a wake vortex. The examiner has established that the vortex generators of the prior art meet the structural aspects recited in the apparatus claims. As such, the prior art vortex generators are deemed capable of achieve the acts or functions included in the claims. Accordingly, because the structure as described by the examiner above meets the elements of the vortex generators recited in the apparatus claims, it follows that the vortex generators are deemed quite capable of achieving the acts or functions included in the apparatus claims.

Hence, contrary to applicant's apparent position regarding burden of proof, the burden does shift to applicants to show that the devices of the prior art are not capable performing the claimed function. See *In re Ludtke,* 441 F.2d 660, 664, 169 USPQ 563, 566-567 (CCPA 1971) (since alleged distinction between applicants' claims and

reference is recited functional language, it is incumbent upon applicants to show that device disclosed by reference does not actually possess such characteristics).

With regard to the method claims, the recited method is considered disclosed by the prior art as emphasized in the rejections above. It is clear that the prior art vortex generators each either produce (as emphasized above) or are most capable of producing countercurrent vortices along the axis of the main flow as seen in one or more the drawing figures. The prior art vortex generators each inject a targeted flow of a secondary fluid medium into the vortices generated by the surfaces of the vortex generators with the targeted flow being approximately in the direction of the main flow. Since the prior art above teaches that the production of the vortices (such as the number of turns and the location of the vortex breakdown, if desired) are determined by the incidence angle and sweepback angle that are suitably selected according to the application in which the vortex generators are employed, the prior art devices, taken as a whole, are considered to do as such but are also quite capable of introducing the axial impulses of the secondary flow into any desired region of the vortex as determined by the vortex generator geometry.

Applicant also refers to alleged advantages of the invention such as increasing the axial speed of the vortex and such a result would likely be inherent from the influence of the injected secondary flow in the prior art methods outlined above, however, such arguments are of no patentable consequence because it is well settled that features not claimed may not be relied upon in support of patentability. *In re Self*, 671 F.2d 1344, 213 USPQ 1 (CCPA 1982). Although a claim should be interpreted in

light of the specification disclosure, it is generally considered improper to read limitations contained in the specification into the claims. See *In re Prater*, 415 F.2d 1393, 162 USPQ 541 (CCPA 1969) and *In re Winkhaus*, 527 F.2d 637, 188 USPQ 129 (CCPA 1975), which discuss the premise that one cannot rely on the specification to impart limitations to the claim that are not recited in the claim.

Limitations not found in the language of a claim cannot be read into the claim. *E. I. Du Pont de Nemours & Co. v. Phillips Petroleum Co.*, 849 F.2d 1430, 7 USPQ2d 1129 (Fed. Cir. 1988). Limitations appearing in the patent specification cannot be read into the claims. Id. Nor is it permissible to inject into claims limitations referred to in the prosecution history. *Intervet America, Inc. v. Kee-Vet Labs, Inc.*, 887 F.2d 1050, 1053, 12 USPQ2d 1474, (Fed. Cir. 1989).

In conclusion, the amendments (and lack thereof) made in the instant application are not deemed of a substantive nature to define over the prior art and thus the rejections are considered proper.

Conclusion

14. **THIS ACTION IS MADE FINAL.** Applicant is reminded of the extension of time policy as set forth in 37 C.F.R. § 1.136(a).

A SHORTENED STATUTORY PERIOD FOR RESPONSE TO THIS FINAL ACTION IS SET TO EXPIRE THREE MONTHS FROM THE DATE OF THIS ACTION. IN THE EVENT A FIRST RESPONSE IS FILED WITHIN TWO MONTHS OF THE MAILING DATE OF THIS FINAL ACTION AND THE ADVISORY ACTION IS NOT

MAILED UNTIL AFTER THE END OF THE THREE-MONTH SHORTENED STATUTORY PERIOD, THEN THE SHORTENED STATUTORY PERIOD WILL EXPIRE ON THE DATE THE ADVISORY ACTION IS MAILED, AND ANY EXTENSION FEE PURSUANT TO 37 C.F.R. § 1.136(a) WILL BE CALCULATED FROM THE MAILING DATE OF THE ADVISORY ACTION. IN NO EVENT WILL THE STATUTORY PERIOD FOR RESPONSE EXPIRE LATER THAN SIX MONTHS FROM THE DATE OF THIS FINAL ACTION. ANY RESPONSE FILED AFTER THE MAILING DATE OF THIS FINAL REJECTION WILL BE SUBJECT TO THE PROVISIONS OF MPEP 714.12 AND 714.13.

15. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Charles E. Cooley whose telephone number is (571) 272-1139. The examiner can normally be reached on Mon-Fri. All official facsimiles should be transmitted to the centralized fax receiving number 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Charles E. Cooley
Primary Examiner
Art Unit 1723

13 December 2005